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ORTHOPHOTOGRAPH PRODUCTION IN URBAN AREAS

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Abstract

This paper investigates possible solutions to the problem of urban orthophotography. Extensive work has been carried out to attain the best possible results, using all the existing software in the Department of Geomatic Engineering, University College London. Two of the most promising methods, which yield the best results, are analysed further. New routines were written in C language, as additions to the existing software, to allow for the special problems that arise in urban areas. The final results overcome the problem of double mapping (or occlusions) and will potentially enable even greater success to be achieved. A simple accuracy assessment of the results has been made. Difficulties and current limitations are analysed and presented.

Key words: orthophotography, urban imagery

Introduction

Orthophotography, which is a well-known alternative to line mapping, has evolved rapidly in recent years due to developments in computing and technology. It has many advantages over traditional line mapping and many more applications. The fact that orthophotographs are an excellent backdrop for a GIS is a strong incentive for further investigation. Due to the concentration of people in large towns, the GIS community is being directed towards urban applications and therefore urban orthophotography is needed as a backdrop. Another interesting application which involves urban orthophotography is three dimensional city visualization.

Orthophotographs may be a robust solution for rural areas, but problems arise when they are applied to urban areas, particularly at large scales. The main difficulties and limitations are the double mapping effect, displacement, and concealment of information by high buildings. The aims of the project described in this paper were to investigate ways to overcome these problems and to assess the degree of success that could be achieved. Using existing software at University College London (UCL), it was intended that project results should be balanced in terms of accuracy and visual acceptance, whilst maintaining a maximum level of automation.

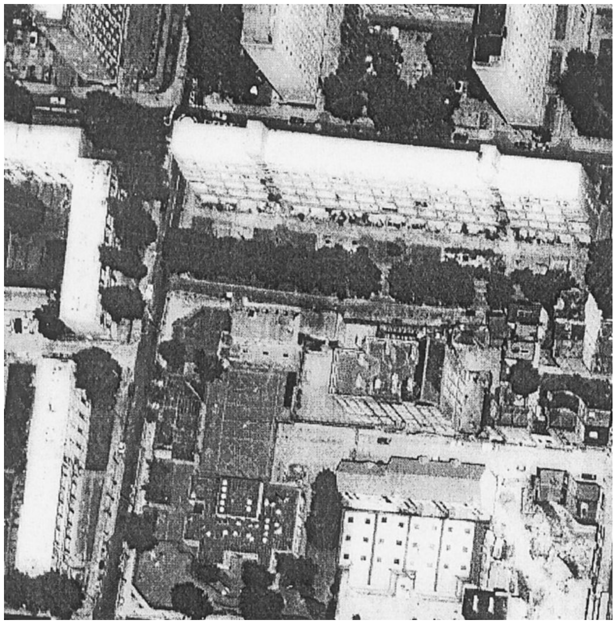

FIG. 1. The area of study on the left photograph.

Data and Software Available

The existing software included Phodis ST, OrthoMax, Erdas Imagine, Arc/Info and HIPS, a command line image processing package developed in house.

Two aerial photographs were available, taken over the Bloomsbury region of central London at 1:5500 scale. This part of London contains many high buildings, such as the British Telecommunications tower. The area of study, unfavourably positioned towards the edge of the photography, is 200×154 m in extent and includes buildings with heights of between 3 m and 30 m (Fig. 1). The calibration report of the camera was available; the focal length of the lens of the camera used for photography was 153 mm. The photographs were scanned at 42 μm with a Sharp JX-600 scanner.

The ground control points (GCPs) available were road junctions in the area, digitized from Ordnance Survey 1:1250 scale maps, last revised in the early 1950s. These points might not have been the perfect choice, but the project was initially conceived as a feasibility study on orthophotograph production.

Lester (1995) had manually collected points over an area of 200×154 m in order to form a digital elevation model (DEM). The spacing of these points was 2 m and they were obtained using the Kern (Leica) DSR analytical plotter at English Heritage. The DEM is shown in Fig. 2.

METHODOLOGY

Two principal methods were used in the project: merging and fine DEM. A simple accuracy assessment was carried out on the best orthophotograph from each method.

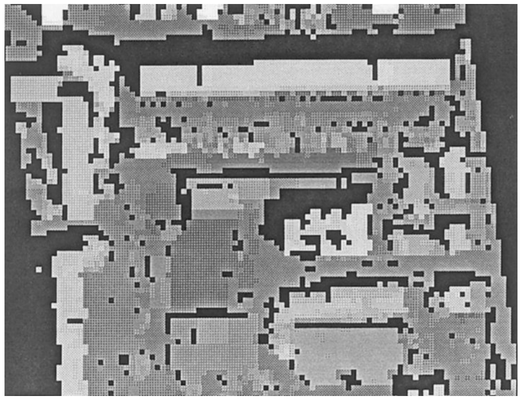

FIG. 2. The manually collected DEM with 2 m spacing. The black pixels are "void" pixels which were not measured due to occlusions.

The Merging Method

This method was first introduced by Jensen *et al.* (1994). Two DEMs are created and then used to produce two different orthophotographs. One DEM is created from the building points (using points on the roof tops) and the other from the remaining points, called the ground DEM. The reason for using two DEMs is to compensate for the large altitude differences between the ground and roof top points, which produce steep slopes in the DEM surface, resulting in an orthophotograph with many errors. Each DEM is used to produce the corresponding orthophotograph. Theoretically, in each orthophotograph the corresponding features will be positioned correctly. Hence by using the correct parts from each orthophotograph, it is possible to create a single correct othophotograph. The vectors of the buildings are also required for data input; these were collected manually.

The Fine DEM Method

The fine DEM method, introduced by Ecker (1992), uses a single very good DEM which models the buildings in an optimum manner. The façades of the buildings should be as steep as possible, which can only be achieved with a dense DEM. It can then be ensured that the building façade appearance is minimal and equal at most to the DEM step. With this method, the vector information for the buildings is still required, collected manually.

There are two alternative procedures for employing the fine DEM method: one step and two step. In the one step procedure, densification and the vector information are used in a single step to produce the fine DEM. In the two step procedure, the first step makes the ground DEM more dense and the second step models the buildings by "raising" the points which are inside the building polygons.

During the fine DEM process, it was possible to mark the DEM pixels hidden behind buildings where there was no information available and therefore it was possible to mark the corresponding pixels in the orthophotograph.

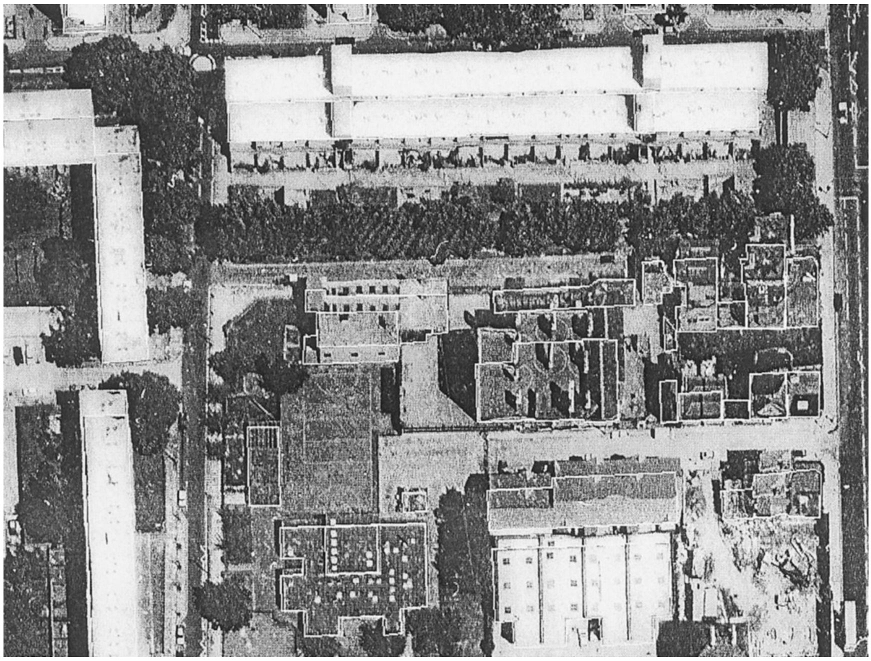

FIG. 3. The merged orthophotograph using 3DIM. The vector information is overlaid for accuracy assessment and also indicates the areas which were "cut" from the building orthophotograph.

PROCEDURES AND RESULTS

Different software packages were used at different stages of the two methods (for example, OrthoMax, Phodis ST and HIPS were used for orthophotograph production; 3DIM, Arc/Info, Phodis ST and OrthoMax were used to create DEMs). In this paper it is not possible to give details of all the work carried out, so the most representative results for each method are described.

It should be mentioned that because multiple systems were used, different model orientations were made and therefore degradation of the overall accuracy could be expected. For both methods it was necessary to collect the building vector information, which was achieved using an analytical stereoplotter (DSR with CADMAP software).

The Merging Method

Both the partial orthophotographs and the corresponding DEMs were produced using the 3DIM software. The .dxf file, with the closed polygons representing the buildings, was employed to produce a mask, which was used to add the closed polygons with the image rooftops in the ground orthophotograph. The double mapping effect was not avoided (Fig. 3).

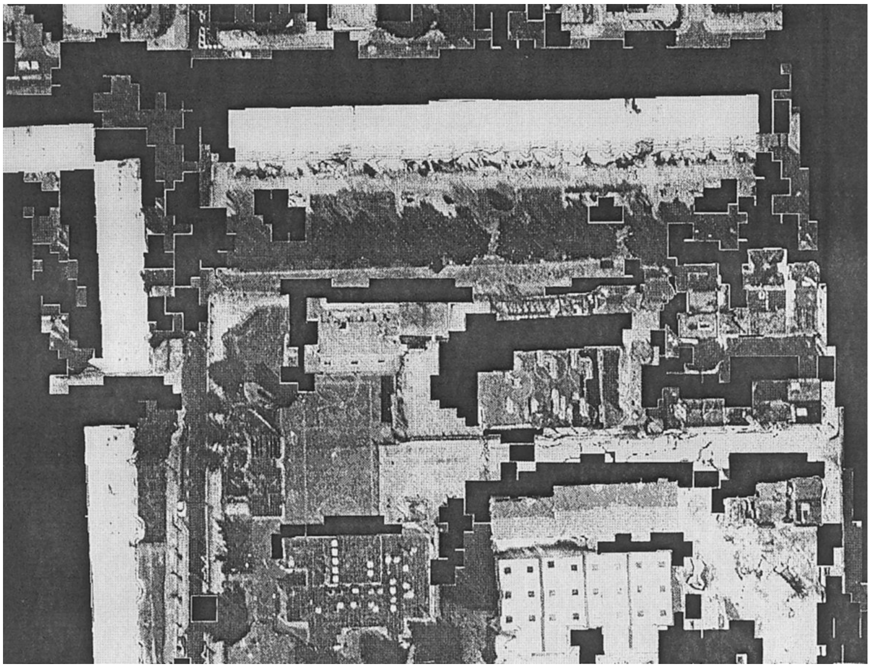

FIG. 4. The orthophotograph created by the fine DEM method, with 0·25m pixel size.

The Fine DEM Method

This method was implemented using the 3DIM software which could be customized more easily than other packages. Three routines were written in C programming language and introduced into the procedure.

The first routine was used to filter the initial DEM for single void pixels which produced aesthetically poor effects in the final orthophotograph. In practice, the routine was able to fill in even bigger gaps of up to 8 pixels, based on the number and formation of the pixels, which were user defined parameters.

The second routine was used for densification of the DEM. The input consisted of DEM points, the vector information and the output DEM spacing. The DEM with increased point density was produced with the following constraints:

(1) the void pixels/points should be maintained;
(2) all points in the building polygons should have the polygon height or the nearest building point height; and
(3) the remaining ground pixels should be assigned values using either bilinear interpolation or nearest neighbour method (if the new pixel is next to a building rooftop and the bilinear interpolation is impossible, the height value should be assigned from the nearest ground point).

The third routine was the inverse camera model, modified to compensate for the void pixels in the DEM where no information should be printed on the final orthophotograph. The result is shown in Fig. 4.

TABLE I. Results from check points.

	Left image		*Right image*	
Method	*R.m.s.e. X (m)*	*R.m.s.e. Y (m)*	*R.m.s.e. X (m)*	*R.m.s.e. Y (m)*
Fine DEM	0·256	0·252	0·209	0·246
Merging	0·366	0·364	0·336	0·325

Accuracy Assessment

In order to examine accuracy, 14 points were measured on a digital stereoplotter (with Phodis ST) using the same digital imagery and model orientations as employed for the orthophotograph production. Five ground points and eight building corners were selected as check points. The same points were then also measured on the orthophotographs. The results are given in Table I.

CONCLUSIONS AND DISCUSSION

At the beginning of this project, the main query concerned the possibility of producing orthophotographs of an urban area such as the centre of London. At the end of the project, not only were aesthetically good orthophotographs produced, but the occlusion areas were automatically marked as part of the orthophotograph production algorithm and the assessment proved that the final results are sufficiently accurate to fulfil requirements for mapping. It should not be hastily concluded that all problems of urban orthophotography have been solved. In the author's opinion, further research should be focused on automation.

The merging method is simple and easy. It has been proved that the procedure can be fully automated. The main disadvantage of this method is the manual acquisition of the necessary vector information. It does not need a detailed DEM with a large number of points, in comparison with the fine DEM method which needs ample points to exactly describe the three dimensional man-made objects. With the merging method, the necessary vector information may be used, in addition to the building points, for the production of the building DEM and therefore improve the accuracy. It is also possible to use only the vector information to form the building DEM using a TIN structure and hence reduce the acquisition time if DEM points are being collected manually. On the other hand, the coarse DEMs used may lead to loss of accuracy in comparison with the fine DEM method. If the orthophotographs are going to be used as backdrops in a GIS, then the merging method is the better method to use, since it is not as demanding as the fine DEM method. Another disadvantage of the merging method, as implemented in this project, was the difficulty of identifying building corners due to the double mapping effect.

The fine DEM method, as applied in this project with purpose written software, managed to overcome the problems of occluded areas and to map buildings successfully. It is difficult to implement because manual collection of information is time consuming and purpose written software is needed. However, it produces more accurate results and it is possible, with an extension of the basic fine DEM procedure, to fill in missing information from other orthophotographs based on the black areas of the existing orthophotograph. The camera model is robust and therefore estimation of occluded areas on every photograph is possible (Amhar and Ecker, 1996). The vector information available could be used to reduce manual collection of points. The densification program of the DEM can work even without points in the polygons.

A very dense DEM is needed in order to obtain good results in terms of accuracy and presentation. Manual collection of a very dense DEM in urban areas is not economical and existing automated techniques will produce strange effects. The use of breaklines and manually collected points to produce a good DEM with commercial software failed. One problem with commercial software is that the orthophotograph algorithm cannot accommodate void pixel values and mark the appropriate areas in the orthophotograph as occlusion areas. A further problem with such software is that it can only treat vector information as breaklines and not as building rooftops. For example, when a commercial program calculates the height of a new point between a ground point and a "breakline" (building vector), it uses interpolation, but this point should be assigned either the height of the nearest ground point or the height of the rooftop, depending on which side the new point is located. With the breakline system the new point is assigned an average value, which is not correct. The program created at UCL addresses such problems, which is why it manages to yield good results. It should be noted at this point that, according to Ackermann (1994), image matching techniques are promising and better accuracies should be expected. In the author's opinion, it should also be anticipated that a "clever" matching algorithm will be developed that can appoint a void value to DEM points which do not appear in both photographs (occlusion areas).

The assessment of the best orthophotographs delivered an average error of 0·26 m. It is realistic and quite safe to examine the map scale based on the expected accuracy, which is 0·2 mm on the map. In that case, the r.m.s.e. of 0·26 m fulfills the requirements of a 1 : 1300 scale map or orthophotomap. With better model orientation and higher photographic resolution, 1 : 1250 scale map requirements could be fulfilled. Under certain circumstances (appropriate focal length and better position of the test area on the aerial photographs), even mapping at 1 : 1000 scale could be considered.

Model orientation in photogrammetry is crucial to the accuracy. Usually model orientation, DEM creation and orthophotography production are carried out with a single system. Therefore both the DEM and the orthophotographs are created using the same model orientation and thus better accuracy should be expected.

The only valid difficulty that remains is acquiring the necessary vector information, which is collected manually at present. This problem is currently being investigated in research into three dimensional city modeling. A number of teams at various universities are trying to achieve a solution and some progress should be expected in the near future (Kim and Muller, 1994).

The orthophotograph algorithm yields no problems and all the procedures can be automated. The main limitation seems to be the automated collection and creation of a satisfactory DEM for the explicit situation of urban areas. In the author's opinion, anticipation of the occluded areas and filling in the missing information from adjacent photography can be achieved quite easily; therefore potentially all the problems of urban orthophotography will be solved in the near future.

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Résumé

On passe en revue dans cet article les solutions permettant de résoudre le problème de l'orthophotographie en zone urbaine. On a fourni des efforts intenses au Département de Génie Géomatique de "l'University College London", pour obtenir les meilleurs résultats possibles, en utilisant tous les logiciels qui y étaient disponibles. On procède à l'analyse de deux des méthodes les plus prometteuses, celles qui ont fourni les meilleurs résultats. On a écrit de nouveaux sous-programmes en langage C qui s'ajoutent aux logiciels existants, et sont adaptés spécialement aux problèmes des zones urbaines. Les résultats montrent qu'on a pu finalement surmonter le problème des dédoublements (ou des lacunes) dans la cartographie et que l'on pourra même obtenir encore de plus grands succès. On a pu évaluer simplement la précision des résultats. On analyse et l'on expose les difficultés correspondantes et les limitations actuelles.

Zusammenfassung

In dem Beitrag werden mögliche Lösungen des Problems der Orthophotographie in urbanen Gebieten erörtert. Umfangreiche Arbeiten wurden durchgeführt, um die bestmöglichen Ergebnisse zu erhalten, wobei alle in der Dept. of Geomatic Engineering, UCL *vorhandene Software genutzt wurde. Zwei der meistversprechenden Verfahren, die die besten Ergebnisse lieferten, werden weiter untersucht. Neue Programme wurden in der Sprache C geschrieben und bilden eine Ergänzung zur bestehenden Software, um die speziellen Probleme in Siedlungsgebieten zu lösen. Die Endergebnisse lösen das Problem der Doppelabbildung (oder Abdeckung) und werden möglicherweise zu besseren Ergebnissen führen. Für die Resultate wurde eine einfache Genauigkeitsabschätzung durchgeführt. Schwierigkeiten und gegenwärtige Grenzen werden analysiert und aufgezeigt.*